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Larsen, Jeppe Veirum; Moeslund, Thomas B.; Overholt, Daniel

Published in:

Replace, Repair, Restore, Relieve – Bridging Clinical and Engineering Solutions in Neurorehabilitation

DOI (link to publication from Publisher):

[10.1007/978-3-319-08072-7_74](https://doi.org/10.1007/978-3-319-08072-7_74)

Publication date:

2014

Document Version

Publisher's PDF, also known as Version of record

[Link to publication from Aalborg University](#)

Citation for published version (APA):

Larsen, J. V., Moeslund, T. B., & Overholt, D. (2014). Exercising the Tibialis Anterior Muscle of Children with Cerebral Palsy for Improved Neuroplasticity using an Electrical Guitar. In W. Jensen, O. Kæseler Andersen, & M. Akay (Eds.), *Replace, Repair, Restore, Relieve – Bridging Clinical and Engineering Solutions in Neurorehabilitation: Proceedings of the 2nd International Conference on NeuroRehabilitation (ICNR2014)*, Aalborg, 24-26 June, 2014 (Vol. 7, pp. 501-505). Springer Publishing Company. https://doi.org/10.1007/978-3-319-08072-7_74

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Exercising the Tibialis Anterior Muscle of Children with Cerebral Palsy for Improved Neuroplasticity using an Electrical Guitar

Jeppe V. Larsen, Thomas B. Moeslund and Dan Overholt

Abstract— This paper is a suggestion on how to improve or extend a known method of exercising the tibialis anterior muscle for improved mobility for children with cerebral palsy through neuroplasticity. We suggest that by using slightly altered existing devices, in this case the Actuated Guitar, it is possible to motivate children to do functional activities as regular exercises and that it will provide better results when compared to traditional exercises.

Keywords: Rehabilitation, Musical Instrument, Neuroplasticity, Motivation, Cerebral Palsy.

I. INTRODUCTION

People with Cerebral Palsy often have lowered functionality of the tibialis anterior muscle, which is the front facing muscle on the lower leg covering the length of the shin. Having problems to activate the tibialis anterior muscle results in difficulty doing dorsiflexion of the foot, that is, lifting the tip of the foot upwards. Normally dorsiflexion is working in tandem with plantarflexion, that is stretching the foot away from the knee. This is for example used when walking, and help positioning the foot in the right angle producing a smooth and normal gait cycle. Lack of control or strength in the tibialis anterior muscle can results in the characteristic tiptoe gait often seen on children with cerebral palsy. What happens is that following a planterflexion the tibialis anterior muscle is not strong enough or not activated properly and a full dorsiflexion is not executed causing the toe to touch the ground first when walking. This makes it difficult to walk and even more difficult to walk in rough or non flat terrain. This uneven gait makes it extra tiring for children with cerebral palsy to follow along in the tempo of normal children. Therefor rehabilitation of children with cerebral palsy has often focus on training the tibialis muscle to improve gait and mobility.

II. METHODS

A. Traditional Training of the Tibialis Anterior Muscle

A common technique used to strengthen the tibialis anterior muscle is a simple repetitive exercise of the isolated muscle using a device designed for the purpose, see figure 1. You simply put weight on the front of the foot and the user lifts the foot as high and as many times he or she can. The device is often used in combination with other exercises such as long walks or walking in different and difficult terrains.

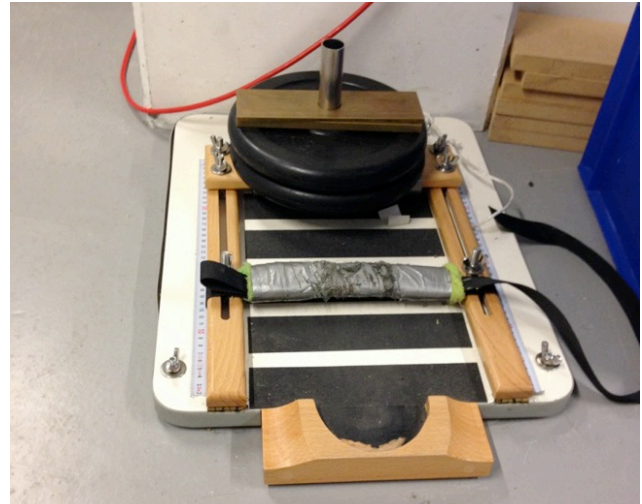


Figure 1: An example of a device used to train the tibialis anterior muscle. The heel is placed in the cutout and the tip of the foot under the strap. Weight and size can be customized. - Image provided by Jakob Lorentzen from the Helena Elsass Centret

B. Rehabilitation and neuroplasticity

Neuroplasticity refers to the brain's remarkable ability to rearrange areas in the brain previously used for other specific tasks. The idea is that if an area of the brain has been damaged that information or functionality can relocate to an undamaged area of the brain. Advances within this area will be extremely important and helpful for people with brain injuries like cerebral palsy or stroke victims. Studies show that by doing 400 – 600 repetitions a day exercise can lead to structural neurological changes [1][2][3]. There is still a lot to discover regarding neuroplasticity and how to optimize and target specific areas and functionality of the brain.

The type of repetition used in rehabilitation is also important. *Passive exercise* is where a therapist is performing or aids the patient in moving a limb opposed to an *active exercise* where the patient performs a conscious action himself. When talking neuroplasticity active exercise is the only type that have showed any results. [1].

C. Motivation through functional activity

For children repetition without any apparent goal is quickly becoming a boring task. The best rehabilitation is the exercises that the child will do by itself in his or her own context and by own free will. As stated in the section above a high number of repetitions every day is needed to achieve the desired results and therefor motivation is the key for a positive result. An indirect way to accomplish this is by functional activity exercise [1]. A functional activity is an exercise that has a purpose e.g. picking up a glass. If the active exercises can be either replaced or supported by functional activities in their everyday lives and interests or

hobbies of the child the chances for self supported continuous rehabilitation will be a lot higher.

D. The Actuated Guitar

Musicians' brains have often been used as models for neuroplasticity because the plasticity is rather extreme in the brains of musicians [5]. One of the reasons why the changes are more pronounced can be because music performance requires, that a high number of areas of the brain are working simultaneous to coordinate the body and on the same time interpreting what it is hearing and reacting accordingly [5].

An example of a device that can be used to do functional exercise in a musical context is the Actuated guitar [4], see figure 2. The actuated guitar was developed to give people with hemiplegia cerebral palsy, stroke victims or similar disabilities the ability to play on a real electrical guitar. User studies were conducted during the 2013 Summer Camp at the Helena Elsass Center[6] and showed that children with no prior musical training were able to produce rhythmic strumming patterns using their non affected foot and thereby over time be able to operate and play the instrument.

The system allows for a wide variety of input devices that make an expandable and divers rehabilitation tool that can be used in many different areas.



Figure 2: The Actuated Guitar. The actuator pulling the pick across the strings is a motorised fader from a mixing console. The motor is controlled via a Arduino microcontroller and a 2Motor motor controller mounted inside the guitar's body.

E. Functional Activity-Based Training of the Tibialis Anterior Muscle

Our hypothesis is that, using a foot pedal as input to control the Actuated Guitar, see figure 3, it is possible to setup at functional activity that will facilitate the same movement patterns as the traditional exercise. The goal is to compare if the functional activity's effect on neuroplasticity is greater than the traditional exercise, not the muscle building capabilities.

The studies should be longitudinal when dealing with neuroplasticity networks because it is time consuming, probably 3 – 6 months. First part of the evaluation will be a qualitative evaluation focusing on how the different exercises motivate the children. Are the guitar and its possibilities more motivating over time compared to the traditional exercise? The second part will be a series of test

to determine if the children's has gained better control of the tibialis anterior muscle.



Figure 3: The pedal used for strumming the guitar. The height of the pedal will increase or decrease the angle X and thereby alter the difficulty and the intensity of the exercise.

III. DISCUSSION

The idea of using existing or slightly altered technologies to replace or improve existing rehabilitation has numerous benefits. First of all, making people able to rehabilitate through existing devices and initiatives can significantly cut down costs. Enabling people with e.g. CP to play a real guitar opens up a world of opportunities they would otherwise not be able to explore. If they got a one of a kind custom made instrument, there will be no one to teach them how to play the custom made instrument. They will not be able to identify with artists playing that instrument, they will not be able to identify their instrument in popular music, they will not be able to find inspiration, sheet music or watch videos of performances the internet. It will be more or less impossible to keep up a long-term motivation. With a solution like the Actuated Guitar, people can use all the initiatives like every normal child. By doing just enough scaffolding long-term motivation is possible and will be fed by the children's own desire for learning and through that continuous exercise with a high number of repetitions which will increase the benefits of neuroplasticity.

ACKNOWLEDGMENT

Funding for this work was provided in part by a grant from Ludvig og Sara Elsass Foundation.

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